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PRELIMINARY RESULTS OF THE INVESTIGATION OF THE MARTIAN ATMOSPHERE WITH THE MARS-2 SATELLITE

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16. Abstract Purpose: Radioscopy at $\lambda = 32$ cm was performed. Frequency changes gave refraction indices, which depend on electron concentration (ionosphere) and P and T (troposphere), and are found as a function of altitude, which turns out to be exponential. Temperature gradients found were low -- less than 1.5°K/km altitude. Curves of P, f change, and electron concentration are given. Parameters found include: pressure near the nominal surface, 7.0 ± 2 mbar; concentration of atoms [sic] at the surface, $(2.3 \pm 0.7)\cdot 10^{17}$ cm^{-3}; temperature at 10 km altitude, 220 ± 20°K; corrected height of the troposphere, 11 ± 4 km; electron concentration in the lower ionospheric maximum, $(7.5 \pm 2)\cdot 10^{4}$ cm^{-3}; electron concentration of the overall ionospheric maximum, $(1.7 \pm 0.2)\cdot$ $\cdot 10^{5}$ cm^{-3}; altitude of the overall maximum, 138 ± 4 km; depth of the ionosphere in the region 150-250 km, 35 ± 10 km; altitude of the normal lower maximum, 110 ± 4 km.

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PRELIMINARY RESULTS OF THE INVESTIGATION OF THE MARTIAN ATMOSPHERE WITH THE MARS-2 SATELLITE

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While the Mars-2 space vehicle was circling Mars, numerous /1071* radioscopic observations of the Martian atmosphere were made with radio waves in the λ = 32 cm band. Variation of the signal parameters gave information on the physical characteristics of the troposphere and ionosphere. Changes in the radio wave frequency caused by the atmosphere are directly proportional to the angle of refraction, which is uniquely connected with the variation of the index of refraction with altitude above the planetary surface. Thus, curves of the index of refraction of radio waves vs. altitude above the planetary surface were obtained. The index of refraction of radio waves is determined by the electron concentration in the ionosphere, and the pressure and temperature in the troposphere of the planet. The radio probe method yielded vertical profiles of the atmosphere in the equatorial regions of Mars. The measurement results were related to altitude above the planetary surface by comparing trajectory data with the incidence times of the beams on the surface of Mars, which times were determined using diffraction curves of the field intensity variation. As an example, Fig. 1 shows frequency variations caused by the Martian atmosphere as a function of time. (Sections a, b, and c represent the successive radioscopy of the upper part of the ionosphere, the lower region of the ionosphere, and the troposphere of the planet, respectively.)

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* Numbers in the margin indicate pagination in the foreign text.

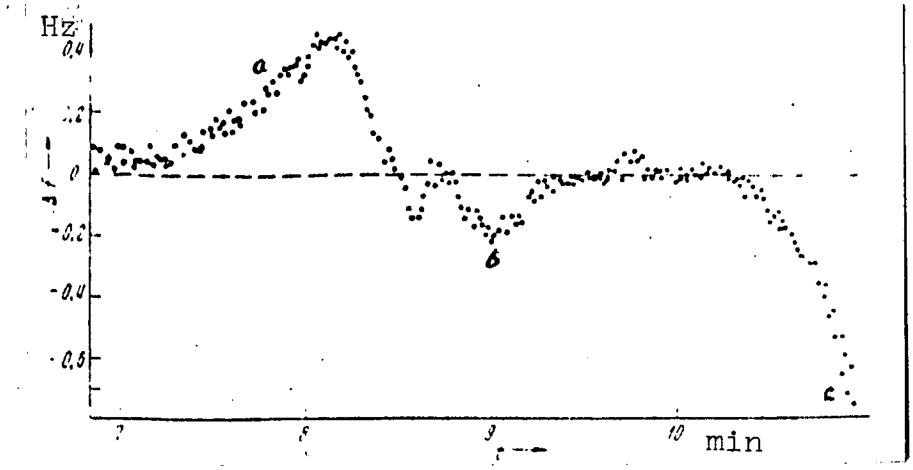

Fig. 1. Frequency variation in radioscopy of the Martian atmosphere.

The study of the troposphere of Mars showed that the refraction angle varies exponentially with altitude, which indicates a weak dependence of temperature on altitude. The corrected tropospheric altitudes in various regions of the planet varied between 10 and 13 km. The average temperature of the troposphere was determined from the corrected altitudes found. The temperature in the troposphere showed decrease with altitude. However, in the experiments analyzed, temperature was not observed to vary in the altitude region 0-20 km, within the limits of precision of the measurements. The vertical temperature gradient at these altitudes did not exceed 1.5°K/km. The temperature of the troposphere in various experiments was 200-250°K; more accurately, these values pertain to an altitude of 10 km.

The pressure near the surface recorded in various regions of the planet was 5-10 mbar. Since the precision of measurement of the pressure near the surface was around 15%, the surface pressure differences can be explained by the topography of the planet. According to our data, the studied regions of Mars have topographical features which differ from the mean by ±4 km of altitude. Fig. 2 is a plot of pressure vs. height in the Martian troposphere from the data of three experiments. The vertical segments indicate the precision of measurement. Since the pressure near the surface depends upon topography, we superimposed the curves of Fig. 2 at the point where the pressure equalled 5 millibars, and introduced an arbitrary altitude zero. The numbers /1072 of the curves 1, 2, and 3 correspond to experiments carried out on 15, 18, and 21 Dec. 71. In the interpretation of the radio data it was assumed that the content of carbon dioxide in the atmosphere is over 90%.

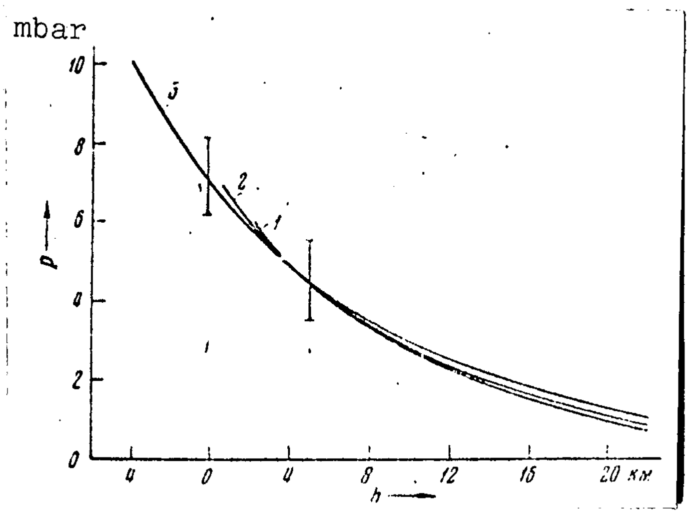

Fig. 2. Pressure vs. altitude over an arbitrary mean Martian surface.

Finding the pressure near the surface by the method of radio frequency radioscopy involves certain difficulties. In the final analysis, the surface pressure is determined from frequency changes at the moment of signal fading when the vehicle is passing over the planetary horizon. It is assumed here that the radio beam touches the surface of the planet. However, the use of a beam representation in this case is not very rigorous. It would be more proper to base the final pressure values on the altitudes above the surface of the set of measurements of various Fresnel zones. Accordingly, the actual surface pressure may be 0.8-1.6 mbar above that obtained in the radioscopy experiments.

Radioscopy of the atmosphere was conducted on the daylight side of Mars, which permitted study of the ionosphere of the planet. The zenith angle of the sun on Mars in the studied regions was 45-50°. The electron concentration of the upper part of the ionosphere there varies approximately exponentially; the depth of the ionosphere in the 250-450 km region in various experiments was between 24 and 47 km. The overall maximum in electron concentration was recorded at altitudes of 134-140 km on different days, and the electron concentration in this region was $(1.4\text{-}1.9)\cdot 10^{5}$ cm^{-3}. The electron concentration fell off at lower altitudes, after which a second maximum was observed. In December, 1971, the electron concentration of the lower maximum varied within the limits $(5.5\text{-}10)\cdot 10^{4}$ cm^{-3}, and its altitude was 107-115 km. At lower altitudes, the electron concentration drops off sharply, but at 65-80 km a third maximum is occasionally observed, with electron concentration on the order of 10^{4} cm^{-3}. /1073

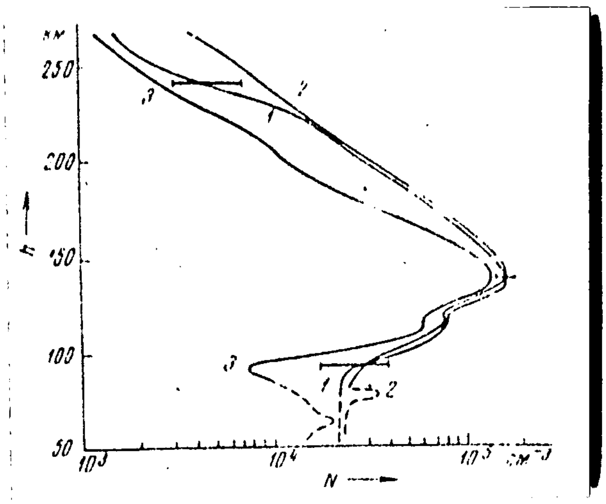

Fig. 3. Electron concentration vs. altitude above surface of planet.

Fig. 3 shows the dependence of electron concentration on altitude on the days of three experiments. The numbering of the curves in this figure correspond to the designations of Fig. 1, with the dates mentioned above, and the horizontal lines indicate the measurement precision.

The Mars-2 satellite made it possible to carry out numerous studies of vertical cross-sections of the Martian atmosphere, in the course of the month. A large volume of factual material on various regions of the planet was acquired. The average parameters which characterize the daytime atmosphere of Mars are given in Table 1.

TABLE 1. AVERAGE PARAMETERS OF THE DAYTIME ATMOSPHERE OF EQUATORIAL REGIONS [OF MARS], FROM THE DATA OF THE MARS-2 SATELLITE

Pressure near the nominal surface, mbar	7.0 ± 2
Concentration of atoms [sic] at the surface, cm^{-3}	$(2.3 \pm 0.7) \cdot 10^{17}$
Temperature at 10 km altitude, $^{\circ}K$	220 ± 20
Corrected height of the troposphere, km	11 ± 4
Electron concentration in the lower ionospheric maximum, cm^{-3}	$(7.5 \pm 2) \cdot 10^{4}$
Altitude of the normal lower maximum, km	110 ± 4
Electron concentration of the overall ionospheric maximum, cm^{-3}	$(1.7 \pm 0.2) \cdot 10^{5}$
Altitude of the overall maximum, km	138 ± 4
Depth of the ionosphere in the region 150-250 km, km	35 ± 10
Electron concentration at 200 km altitude, cm^{-3}	$(3.4 \pm 2) \cdot 10^{4}$

The parameters of the Martian atmosphere depend upon the topography of the planet, latitude and longitude, the zenith angle of the sun, and other factors. Analysis of the data obtained in radioscopic experiments using the Mars-2 satellite will enable us to develop clarifications of the effect of these factors. Average parameters of the daytime atmosphere of Mars were determined in this work; in this sense, the data presented are preliminary.